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Catch of non-targeted species in the Scotian Shelf and Southern Grand Banks (NAFO Divisions 3NOPs4VWX5Z) Atlantic Halibut Longline Fishery

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Species composition of catches by the commercial longline fishery targeting Atlantic Halibut (*Hippoglossus hippoglossus*) on the Scotian Shelf and Southern Grand Banks (Northwest Atlantic Fisheries Organization (NAFO) Divisions 3NOPs4VWX5Zc) were characterized using at-sea observations from the commercial fishery and Commercial Index phase of the joint Fisheries and Oceans Canada (DFO)-Industry Halibut Survey. Commercial longline sets reporting hook sizes 14-16 are proposed as a method of distinguishing fishing targeting halibut from sets directed for other groundfish species. Observer coverage ranges from 4-13% in NAFO Area 4 and 15-87% in NAFO Area 3 and does not match well with the seasonal distribution of the fishery. Fishing during the summer months has higher observer coverage because of the Commercial Index, but there is low coverage in the months during which highest landings occur: in NAFO Divisions 3NOPs from November to December, in NAFO Divisions 4VW from January to May, and in NAFO Division 4X from August to October. The halibut-directed longline fishery keeps the majority of its catch (70-85% by weight), with the majority of the retained catch being halibut. Species composition of observed catches varies geographically and seasonally. The main retained non-target species are Atlantic Cod, White Hake and Cusk. The main non-retained species are Barndoor Skate and other skates. Given the geographic and seasonal changes in relative abundance and catchability of halibut and other species, total bycatch is estimated by scaling observed catches summed by area and season by the proportion of halibut landed during halibut-directed fishing. Notably, while the proportion of non-target species in the catch of the halibut-directed longline fishery has been decreasing, with increasing halibut total allowable catch, the total catch of non-target species could increase.

Prises d'espèces non ciblées dans la pêche à la palangre du flétan sur le plateau néo-écossais et dans le sud des Grands Bancs (divisions 3NOPs4VWX5Zc de l'OPANO)

RÉSUMÉ

La composition par espèces des prises de la pêche commerciale à la palangre ciblant le flétan (*Hippoglossus hippoglossus*) sur le plateau néo-écossais et dans le sud des Grands Bancs (divisions 3NOPs4VWX5Zc de l'Organisation des pêches de l'Atlantique Nord-Ouest [OPANO]) a été caractérisée par des observations en mer effectuées par la pêche commerciale et la phase d'indice commercial du relevé sur le flétan effectué conjointement par Pêches et Océans Canada (DFO) et l'industrie de la pêche. Les calées de la pêche commerciale rapportant des tailles d'hameçons entre 14 et 16 sont proposées comme méthode pour distinguer les calées ciblant le flétan des calées dirigées vers d'autres espèces de poissons de fond. La couverture d'observation varie de 4 % à 13 % dans la division 4 de l'OPANO et de 15 % à 87 % dans la division 3, et ne correspond pas exactement à la répartition saisonnière de la pêche. La couverture d'observation de la pêche est plus importante pendant les mois d'été en raison de l'indice commercial, mais elle est faible au cours des mois durant lesquels ont lieu les débarquements les plus importants : de novembre à décembre dans les divisions 3NOPs de l'OPANO, de janvier à mai dans les divisions 4VW, et d'août à octobre dans la division 4X. La pêche à la palangre ciblant le flétan conserve la majorité de ses prises (70 % à 85 % du poids), la majorité des prises conservées étant des flétans. La composition par espèce des prises observées varie sur les plans géographique et saisonnier. Les principales espèces non ciblées conservées sont la morue franche, la merluche blanche et le brosme. Les principales espèces rejetées sont la grande raie et les autres raies. Étant donné les changements géographiques et saisonniers de l'abondance relative et de la capturabilité du flétan et d'autres espèces, l'estimation des prises accessoires totales est réalisée en mettant à l'échelle les prises observées, regroupées par zone et par saison, en fonction de la proportion de flétans débarqués pendant la pêche ciblant le flétan. Notamment, tandis que la proportion d'espèces non ciblées dans les prises de la pêche à la palangre ciblant le flétan a diminué, et que le total autorisé des captures de flétans a augmenté, les prises totales d'espèces non ciblées pourraient augmenter.

INTRODUCTION

Bycatch is the unintended capture of species that were not the target of a fishery, whether they are retained or discarded (Gavaris et al. 2010). Discards are the portion of the catch that is not retained. These are species with no commercial value, life stages of commercial species that must be discarded under management regulations, and/or vulnerable species protected by legislation. At-sea observer data, which records the estimated retained and discarded weight of species on observed sets, has been used to characterize the discards from Canadian fisheries (Gavaris et al. 2010, Campana et al. 2011), for stock assessment of target species (Showell et al. 1993, Showell and Bourbonnnais 1994, Gregoire and Showell 1994, Showell et al. 2005), as well as estimating the mortality of commercial species (O'Boyle et al. 1996, Orr et al. 2001) or species of conservation concern (Hooker et al. 1997, Hoey et al. 2002, Baum et al. 2003, Lewison et al. 2004, Miller and Skalski 2006). At-sea observers monitor and record events in greater detail than can be obtained from the submitted fishery monitoring documents, including the catches of all species, whether retained or discarded, information on the fishing practices, including nature and location of the fishing activity, and also sample fish to assess sex, weight and maturity. The at-sea monitoring information used in this analysis of the catch of non-targeted species in the Scotian Shelf and Southern Grand Banks (Northwest Atlantic Fisheries Organization (NAFO) Divisions 3NOPs4VWX5Z) Atlantic Halibut (*Hippoglossus hippoglossus*) longline fishery is maintained by Fisheries and Oceans Canada (DFO) Maritimes Region in the Industry Surveys Database (ISDB).

The groundfish fishery on the Scotian Shelf and southern Grand Banks (Figure. 1) is a multi-species fishery with licence conditions that allow the retention and landing of many species such as Atlantic Halibut, Atlantic Cod, White Hake, Haddock, and Greenland Halibut. Other species such as Spiny Dogfish and all species of skates can be landed or discarded. The purpose of this study is to characterize the species composition of the catch in the commercial Atlantic Halibut longline fishery. At present, more than 90% of the halibut landings on the Scotian Shelf and Southern Grand Bank come from longline gear (DFO 2015). All halibut retained and landed in Nova Scotia are weighed out and recorded as fishery landings along with information on fishing activities. This fishery monitoring information is maintained by DFO Maritimes Region in the Maritimes Fisheries Information System (MARFIS) database.

NAFO Divisions 3NPsO4VWX5Zc is a large management unit, and the species composition of the catch in any one location is unlikely to be representative of the entire area. Not only does such a large management unit encompass a number of ecological provinces, there are also variations in the nature of the fishery throughout the management unit that could influence the composition of the catch. Further, the fishery operates year round and individual species are likely to exhibit seasonal variation in catchability due to life history events and migration in and out of a fishing area.

The bycatch analysis had four objectives:

1. Describe the halibut longline fishery in NAFO Divisions 3NOPs4VWX. Recognizing that longline fishing is, in some areas, a multispecies fishery, ways of determining what portion of the landings was from halibut-directed fishing were explored.
2. Describe the species composition of observed halibut-directed longline sets by NAFO Division and annual quarter.
3. Compare the distribution of observed sets (commercial fishing and Commercial Index) directed at halibut by NAFO Division, month and year to the distribution of commercial fishing landings.
4. Estimate the bycatch of a selection of species of commercial interest and of special concern.

Analysis of bycatch associated with catching halibut is challenged by the difficulty of defining the halibut-directed fishery. The last bycatch analysis, conducted in 2008 by Trzcinski et al. (2009), used only observed sets targeting halibut from a subset of 15 vessels which were known to direct fishing activities toward catching halibut. The Trzcinski et al. (2009) approach assumed that these vessels were representative of the directed fishery. Here, use of hook size reported in the logbooks is proposed as a means to identify the proportion of total landings that are from halibut-directed fishing. The proposed analysis differs from that conducted in 2008 in three ways. First, the analysis is completed for all NAFO Divisions. Second, all observed halibut-directed longline sets are included and assumed to be representative of the fishery. Third, hook size is used to identify the proportion of commercial longline landings targeting halibut.

METHODS

OBSERVER (ISDB) AND COMMERCIAL LANDINGS (MARFIS) DATABASES

The data used for this analysis includes information from commercial fishing trips carrying observers and from sets observed during the Commercial Index phase of the Halibut Survey. The Halibut Survey is a joint DFO-Industry survey conducted annually on the Scotian Shelf and Southern Grand Bank (DFO 2015). During the commercial index phase, fishing captains choose fishing locations and employ soak times and hook sizes similar to those used during commercial fishing. The commercial fishing sets included were those in which the observer identified halibut as the main species sought. The data collection protocols and data forms used for the Halibut Survey and Commercial Index are consistent with the International Observer Program and the data were uploaded into the ISDB. The data collected by at-sea observers included trip information, set details and location information, as well as detailed individual morphologies on target and non-target species caught during commercial fishing. Here only the catch on halibut directed commercial fishing and the Commercial Index sets were considered as representative of the fishery. Halibut Survey fixed station sets have prescribed protocols and locations that may or may not be representative of commercial fishing.

COMMERCIAL INDEX (ISDB)

Trip and Vessel Information

The vessel name and Commercial Fishing Vessel number are recorded and can be used to identify the boat and access information on length, gross tonnage and break power.

Gear Information

Data was collected to describe both the type of gear and the species sought. For longline trips, the size and number of hooks, length of the gear, duration of set and bait are recorded.

Set Information

For each set, date, depth, geographical position, duration of soak, hook number and size and bait type are recorded. Bait was identified by species or combination of species. The NAFO Division is also recorded.

Catch Data

Catch is identified by species. The estimated total weight (kg) of catch that is retained as bait, for personal use or landed, are recorded as retained. Any catch that is thrown back is recorded as discarded. The total catch is the sum of the estimated retained and discarded weights by species.

Commercial Landings Data (MARFIS)

The total fishing effort for the halibut fishery can be estimated from the number of landing slips, or days fished, in each NAFO Division. A sub-trip, as recorded in MARFIS, is equivalent to a single longline set, but a longline set may vary in the number of hooks, hook size, number of strings and soak time. For all of the analyses, the amount of halibut weight landed was used as a proxy for effort, rather than the number of sets.

HOOK SIZE AS AN INDICATOR OF LONGLINE FISHING TARGETING HALIBUT

The at-sea observer program provides the species composition of caught, retained and discarded species for commercial fishing, and identifies the target species for each commercial fishing event (Atlantic Halibut in this analysis)). Of the halibut-directed commercial fishing sets observed between 2009 and 2013 (n=178), only 2 were completed with otter trawl gear. For the longline commercial fishing sets using hook sizes 14, 15 or 16 observed between 2009 and 2013, 92 % (123 of 134) were directed for halibut and 94% (123 of 131) of halibut-directed longline sets were with hook sizes 14, 15 or 16 (Table 1). Here, the use of hook size is explored, as reported in the logbooks submitted by the commercial fishery, to identify landings associated with halibut-directed longline fishery.

In the MARFIS database, the number of hooks and similar fields are not reviewed for all fisheries. There is currently no regular DFO Science review program for logbooks used to record commercial fishing directing for groundfish so, at present, the hook size field includes a large proportion (18%) of missing data (hook size=0) and some improbable values (2%). Some of these values are attempts to convey information reported by havesters, while others appear to be reporting or data entry errors. For example, on occasion fishermen report the use of two hook sizes. In these cases, there are no protocols for data entry and it appears that the data may be concatenated or averaged, for example a log entry reporting hook size 15/10 might be entered as 1510 or 12.5. Here, only the reports of hook size (10, 11, 12, 13, 14, 15, 16 and 20) were used to assess the proportion of landings with hook size directed toward halibut.

SEASONAL AND ANNUAL TRENDS IN DISTRIBUTION OF FISHERY AND OBSERVER COVERAGE

Trends in the seasonable distribution of commercial landings and observer coverage were compared for NAFO Divisions 3NOP, NAFO Divisions 4VW and NAFO Division 4X by month and year. Observed commercial and Commercial Index sets targeting halibut were identified in the ISDB database by the species sought code. A start date of 1998 was used for the observer time series, the year that the Halibut Survey began and the observer coverage increased. The commercial landings time series covers the years 2002 to 2013. Seasonal and time variations within the two datasets were graphed as a month by year matrix. The entire range in values for each division was divided into 50 bins, with blank cells representing no landings or observed sets and yellow to red representing a gradient of increasing landings or numbers of observed sets.

SPECIES COMPOSITION IN OBSERVED SETS

The bycatch analysis presented in the previous halibut assessment of Trzcinski et al. (2009) included 16 species: Atlantic Halibut; Hake (combined white hake and unspecified hake); Atlantic Cod; Cusk, Haddock; Greenland Halibut (Turbot); three species of wolffish (Northern, Spotted and Striped Atlantic); Greenland Shark; Black Dogfish; and four species of skates (Thorny, White, Winter and unspecified skates). Trczinski et al. (2009) used the category 'Other' to account for the contribution by other less commonly occurring species; for example, Spiny Dogfish and Barndoor Skate, which were found to contribute less than 0.5% to catches totaled over the entire geographic range of the fishery. More species categories were included in this

analysis than the previous analysis because the contribution of some species to total catch was larger than 5% in one or more NAFO Divisions. The additional categories were Spiny Dogfish, Sharks (i.e. Blue Shark, Shortfin Mako and Porbeagle) and Barndoor Skate. Including all halibut-directed sets observed between 1998 and 2013 allowed us to estimate species composition of catches in divisions 4X and 4W; these were NAFO Divisions with too few data to be included in the analyses conducted by Trzcinski et al. (2009). All analyses and graphic displays were prepared using R (R Development Core Team 2007).

Geographic and seasonal variations in species composition were examined by grouping observed catches within a NAFO Division into Quarter 1 (January to March), Quarter 2 (April to June), Quarter 3 (July to September) and Quarter 4 (October to December).

TOTAL BYCATCH

The amount of an individual species retained or discarded in Northwest Atlantic fisheries has been estimated using a simple ratio estimator (Gavaris et al. 2010, Wigley et al. 2008). Here, one of the methods described by Gavaris et al. (2010) is used to calculate discards of a species (sp) based on the landings by weight of the target species:

$$Ratio\ estimator_{SpAQ} = \frac{Observed\ Species\ caught\ in\ area\ A\ in\ quarter\ Q}{Observed\ halibut\ retained\ in\ area\ A\ and\ quarter\ Q}$$

Where area (A) is one of the six NAFO Divisions (i.e. NAFO Division 3N, NAFO Division 3O, NAFO Subdivisions 3Ps, NAFO Division 4V, NAFO Division 4W and NAFO Division 4X) and the calendar year is divided into four quarters (Q). The distinction between NAFO divisions was maintained because of differences in how fishing is conducted (e.g. vessel size and length of trip), differences in species communities and catch composition, and differences in the proportion of the landings observed. Bycatch was estimated separately for each quarter because variations in catch that were expected to occur due to seasonal variability in species behaviour and distribution were apparent in the seasonal catch composition analysis, and the proportion of landings observed varied seasonally. It was decided that location and season effects were more important than inter-annual variation or short-term trends, which allowed the pooling of catches from observed sets for the period of 2009-2013.

Total bycatch for the 2013 calendar year was estimated for species of interest. These were commonly occurring species landed (e.g. Atlantic Cod, White Hake, Haddock) or discarded (e.g. White Skate, Greenland Shark), species listed on Schedule 1 of the *Species at Risk Act* (SARA) (e.g. wolffishes) and species with populations assessed as depleted or considered for assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (e.g. Cusk, White Hake, Thorny, Winter and Smooth skates, Spiny Dogfish, Porbeagle and Blue Shark). Barndoor Skate was identified as a potential species of concern in the longline fishery by Gavaris et al. (2010). Skates not listed above were grouped with unidentified skates because identification of these species was more certain in some years than others, with relatively large amounts attributed to unspecified categories.

The proportion of halibut landed using hook sizes 14-16 was used as to estimate halibut landed by fishing directing for halibut. Total catch of individual species was scaled up to the entire longline fishery by summing across quarters and NAFO Divisions. For example, the total catch of a species (sp) is estimated as the ratio estimator multiplied by the portion of halibut landings from fishing directing for halibut in a given area and quarter, summed over six areas and four quarters:

$$Total_{Sp} = \sum by\ area \sum by\ quarter \left(ratio\ estimator_{SpAQ} * Halibut\ Landings_{AQ} * proportion\ of\ sets\ using\ hook\ size\ 14-16_{AQ}\right)$$

RESULTS

HALIBUT DIRECTED FISHING

An examination of the distribution of observed fishing effort since 2007 (the last year analyzed by Trzcinski et al. 2009) indicated that catches by the 15 index vessels is not representative of the total catch by the current longline fleet. Five of the 15 vessels are no longer active and collective catches by the 15 index vessels while fishing for halibut showed a rapid decline in the amount of catch observed from 145 metric tonnes (mt) in 2009 to 26 mt in 2012 and 0 mt in 2013. Fifteen vessels not considered index vessels were observed, while fishing greater than 10 mt halibut in one or more years since 2007 in NAFO Divisions 3NOPs. In NAFO Divisions 4VWX, longline activity is dispersed across a large fleet in excess of 450 vessels. The number of vessels reporting above average annual landings by division has ranged from 10-21 in NAFO Division 4V, 11-36 in NAFO Division 4W and 30-87 in NAFO Division 4X.

The proportion of landings, with hook size reported, that were directing for halibut (sum hook size 14-16 divided by sum of reporting hook size) were used to estimate the proportion of landings that resulted from targeted halibut fishing. In NAFO Divisions 3NOPs and NAFO Divisions 4VW, almost all landings reported with valid hook size are halibut directed (Table 2). In contrast, only 67% of sets in NAFO Division 4X are halibut directed (Table 3), based on the proportion of sets fished with size 14-16 size hooks.

For this analysis, all Commercial Index and commercial fishing halibut-directed observed sets are used to estimate the total estimated halibut catch. This ratio allows for the observed bycatch to be extrapolated to the total bycatch of the halibut-directed fishery. Observer coverage varied over the management area and quarter (Table 4), with an overall average of 18% between 2009 and 2013. Notably, Division 4X has lowest proportion of halibut-directed longline landings and lowest observer coverage on halibut-directed sets (Table 4).

PROPORTION OF CATCH DISCARDED

Overall the halibut-directed longline fishery retains the majority of its catch (Table 5); and the majority of the retained catch is halibut (Table 6). Of the halibut caught in halibut-directed sets, between 2 and 13% is discarded. Halibut discards are highest in NAFO Division 4X where a greater portion of the halibut caught are under the legal size limit of 81 cm (DFO 2015).

SEASONAL AND ANNUAL TRENDS IN FISHERY DISTRIBUTION AND OBSERVER COVERAGE

Halibut landings have been evenly distributed by month in NAFO Divisions 3NOPs with the exception of the high level of landings in May through July, 2007 (Figure 2). There has been an increase in landings in November and December since 2010. Most of the observer coverage occurs in June during the Commercial Index phase of the Halibut Survey. There has been no observer coverage in January through March since 2010 and coverage in October through December has been sporadic.

In NAFO Divisions 4VW, halibut is landed in all months (Figure 3). Landings have increased in the months January through June since 2002, with 41% of annual landings occurring during January to March. From 2009-2013, landings have been higher in March than April, suggesting a fishing year effect. Observer coverage occurs almost solely during the summer months and has declined to a low level since 2006.

In NAFO Division 4X, most halibut are landed in the months of June through October, with the highest landings occurring in September (19-20% of annual landings) for three of the last five years. Almost all observer coverage of fishing in NAFO Division 4X (Figure 4) occurs on

Commercial Index sets completed during the Halibut Survey (usually June and July, but delayed in 2007 and 2013).

SPECIES COMPOSITION IN OBSERVED SETS

Species composition (by weight) of all halibut-directed observed longline sets from the commercial fishery and Commercial Index from 1998 to 2013 are shown separately for NAFO Divisions 3NOPs and NAFO Divisions 4VWX in Figure 5. Seasonal trends for each area are shown in Figures 6-12. The same colours shown in the legend of Figure 5 are used to identify species in the subsequent bar graphs. From the bottom of the bar to the top, retained species (Halibut, gadids and flounders) are shown followed by wolffishes, sharks (Greenland Shark, dogfishes, pelagic sharks), skates and other species.

In divisions 3NOPs, the annual number of sets observed from 1998-2013 has ranged from 175 to 660 and the total observed estimated catch (all species) ranged from 110-555 mt. From 1998-2006, about 28% of the observed catch was halibut by weight (Figure 5). The year 2007 stands out as one of two consecutive years with the highest amount of observed weight caught (Figures 2 and 5), with the proportion contributed by halibut doubling from the previous year to 54% (Figure 5). It is also a year of higher than average landings of halibut for NAFO Divisions 3NOPs (Figure 2). After 2007, the proportion of the catch represented by halibut increased steadily to a high of 66% in 2012 and 2013 (Figure 5). White Hake was the second most abundant species, contributing 12-42% of the catch from 1998-2006. Its contribution has averaged 8% from 2007 to 2013. Other commonly occurring species in the catch, or species which have contributed more than 10% in one more years, are Atlantic Cod (range 3-25%),Thorny Skate (2-29%), unspecified skates (0-20%), and Northern Wolffish (1-11%). Haddock contributed 16% in 1998, 10% in 2002 and 9% in 2003, but less than 2% in all other years. Other species contributing greater than 1% were unspecified grenadiers and Barndoor Skate.

The annual number of sets observed in NAFO Divisions 4VWX has ranged from 476 to 1065 and the total observed catch ranged from 123-256 mt between 1998 and 2013. The proportion of the catch represented by halibut has ranged from 41-70%, with Atlantic Halibut comprising more 64% of the total catch in the years 2008-2013 (Figure 5). White Hake was the second most abundant species, averaging 11% (range 4-19%) of the total weight caught, followed by Cusk (10%, range 4-14%) and Atlantic Cod (8%, range 4-13%). Other species contributing greater than 2% in some years were Greenland Shark (5% in 2005), Portuguese Shark (2.5% in 2006) and unspecified dogfishes (assumed Spiny Dogfish; 8% in 2003 and approximately 4% in 2004, 2006 and 2013).

In NAFO Division 3N, from 1998-2013, the composition and proportion of bycatch species were quite variable with year and quarter. The contribution of halibut to observed catches ranged from 12 to 86% over quarters 1, 2 and 3 (Figure 6). There was no observer coverage for the fourth quarter. Abundant species were Thorny and unspecified skates in the first quarter, Striped Wolffish, Atlantic Cod and Thorny Skate in the second quarter, and Thorny and White skates and Striped Wolffish in the third quarter.

In NAFO Division 3O, fishing was observed in all quarters, but the level of observation was low in the first quarter from 1998-2008 and for most of the time series in the third and fourth quarters (Figure 7). The contribution of halibut to the catch was generally higher in the second and third quarters and has been greater than 50% of the total catch in quarters 2 and 3 since 2010. White Hake consistently makes up a large proportion of the catch in all quarters, particularly the fourth quarter. Other abundant species are Greenland Shark (quarter 1), Thorny Skate (quarters 1 and 2) and Haddock (quarters 1 and 2).

In NAFO Subdivision 3Ps, Halibut catches are highest in quarters 3 and 4, but coverage is low (Figure 8). Atlantic Cod and White Hake are a significant proportion of the catch in quarters 1 and 2 and at the beginning of the time series in quarter 3. Other abundant species are Thorny and Winter skates in the first and second quarters, and Cusk in the third and fourth quarters.

In NAFO Division 4V, the level of observation is higher in quarters 1 and 2 than 3 and 4, and low in all quarters in 2013 (Figure 9). Halibut generally comprises more than 30% of the catch in quarter 4, and greater than 40% in quarters 1-3. White Hake is the second most abundant species comprising greater than 10% in most years in all quarters. Other abundant species are Atlantic Cod in quarters 1 and 4 and Cusk in quarters 2 and 3. There is high variation in species comprising 10% or more of the catch between quarters and years; for example, most of the catch in quarter 3 in 2007 was Northern Wolffish. In Quarter 2, Portuguese Shark were 12% of the catch in 2006, and Little Skate and Porbeagle comprised 37% of the 2007 catch. Porbeagle was also abundant in quarter 3 in 2009.

In NAFO Division 4W, the proportion of halibut has been generally above 50% in quarter 3 and above 60% in quarter 1 and in quarter 2 since 2005 (Figure 10). There has been no observer coverage during quarter 4 since 2001. A diverse group of other species was observed in the catch, depending on the quarter. White Hake were abundant in quarter 1 and 2 (range 1-23%) and Cusk in quarters 2 (2-33%) and 3 (4-32%). Other species occurring as greater than 6% of the catch in a quarter in a given year were Quarter 1: Barndoor Skate (8-11% , 2009, 2011-2013), Atlantic Cod (11%, 2010); Greenland Shark (10%, 2000); Quarter 2: Spiny Dogfish (13%, 1999); Black Dogfish (14%, 2004); Greenland Shark (15%, 2004); Northern Wolffish (10%, 2005); Barndoor Skate (6%, 2009; 11%, 2011); Quarter 3: Greenland Halibut (7-9%, 2007; 2008, 2012); unidentified wolffish (7-16%, 2006, 2007, 2009); and Barndoor Skate (8%, 2006, 14%, 2012).

In NAFO Division 4X, observer coverage has been historically low in quarters 1 and 4 and the total amount observed has declined recently in quarter 2 (Figure 11). The proportion contributed by halibut has averaged 48% in quarters 2 and 3, and been generally above 60% since 2008 in quarter 2 and 2007 in quarter 3. The second most abundant species are White Hake in quarter 1 (average 34%) and Atlantic Cod in quarter 4 (average 33%). Diversity of catch in quarters 2 and 3 is more complex. Although Atlantic Cod is generally the second most abundant species, other species with weights comprising greater than 10% of the catch in any year in quarter 2 were Cusk (average 9% over time series), Spiny Dogfish (14% in 2004; 71% in 2003; 14% in 2006) and Winter Skate (25% in 2008). Abundant species in the catch from quarter 3 were Cusk (average 9% over the time series), Spiny Dogfish (25% in 2004; 10% in 2013), Greenland Shark (18% in 2005) and unidentified skates (8% in 2013).

TOTAL BYCATCH

Ratio estimators of species of interest are shown in Table 7. The total estimated bycatch for the calendar year 2013 is shown in Figure 12. Total bycatch in the fourth quarter in NAFO Division 3N and NAFO Division 4V were calculated using quarter 1 ratio estimators because there was no observer coverage during October through December in the years 2009 to 2013. The most abundant non-target species were White Hake and Atlantic Cod, followed by Cusk, Barndoor, White and Thorny skates, all species of wolffishes and all species of dogfishes. The amounts of individual skate species caught are obscured by problems with identifications. White Skate is abundant in observed catches in NAFO Subdivision 3Ps and NAFO Division 3N, although a recently published account of its distribution indicates the species occurs east and north of the Grand Bank (Sulak et al. 2009) outside the Atlantic Halibut management unit.

DISCUSSION

Hook size provides a promising means of identifying the halibut landings from halibut-directed fishing. At present the data available to make this assessment is limited and requires improved quality control. It is possible that fishing with two hook sizes is common in NAFO Division 4X, and the hook size reported underestimates the landings with hook sizes 14 -16, as a combination 10-14 would be entered as 12. To the extent that this occurs, the proportion of the landings associated with halibut-directed fishing in NAFO Division 4X would have been underestimated.

The observed halibut-directed longline fishing has low discarding of undersized halibut and retains most of all the fish caught. Unfortunately, the observer coverage of the halibut fishery is low and primarily associated with Commercial Index fishing. The Commercial Index is completed by a selected group of boats ($n<14$) and occurs only in mid-summer (June to July, except for delays in 2007 and 2013). This means that bycatch from observed trips may not be representative of the whole fishery.

Non-target bycatch varies throughout the management unit, reflecting known changes in the distribution of fish species and possibly associated with variation in fishing practices such as bait, hook size, and depth. The proportion of landings observed also varies by NAFO Division; hence, it is important to appropriately weight the observed bycatch by division and quarter as the species composition of the bycatch may be affected by changes in the seasonal distribution of non-target species relative to halibut and/or seasonal changes in the catchability of non-target species relative to halibut. This is particularly important where there is low coverage in the months during which highest landings occur: in NAFO Divisions 3NOPs from November to December; in NAFO Divisions 4VW from January to May; and in NAFO Division 4X from August to October. Ultimately, more representative distribution seasonally of observer coverage is needed.

Observer coverage across areas and seasons is low, especially in NAFO Division 4X, and there is likely considerable bias in using the ratio estimators to estimate the quantity of non-targeted species discarded or retained by the halibut fishery. However, the estimates here can be used to identify potential conservation concerns and where observer coverage could be increased to produce more certain results. This is particularly relevant for species of concern that may be impacted by the longline fishery. Thirteen bycatch species are listed by COSEWIC and/or pursuant to SARA (Table 8).

A complete literature review of the survival of the non-targeted species was not undertaken. Based on a discard survival study by Nielson et al. (1989), and the recent deployment of pop-up satellite tags on halibut, high survival (77-100%) of halibut is expected. Other groundfish species have swimbladders and the abrupt change in depth during gear retrieval decreases the likelihood of survival, particularly where the halibut fishery is concentrated along shelf and channel edges in deep water. Some portion of discarded skates might survive an encounter for at least a short period if they were released carefully. Skates caught by otter trawls were found to have a short term (up to 72 hours) survival rate of 55% (Enever et al. 2008). Long term survival rates and the difference in trauma due to being in a compacted codend versus hooked on a longline are unknown. A survival ratio of 0.75 was used for Spiny Dogfish when estimating total discards by the longline fisheries in the U.S. Atlantic (Wigley et al. 2008).

The change in methodology makes direct comparison with the previous assessment difficult. Overall, halibut appears to represent a larger proportion of the species composition in the current analysis compared to the analysis completed by Trzcinski et al. (2009). With the increase in abundance of halibut, and the increased catch per unit effort, it is expected that bycatch of non-target species per unit effort may be reduced. However, as halibut quota increases the total catch of non-target species could increase.

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TABLES

Table 1. Number of commercial fishing longline sets observed by hook size and species sought (2009-2013; ISDB query October 15, 2014).

Target Species	Hook size							
	2	12	13	14	15	16	20	1210[1]
Cod	0	15	3	3	2	1	0	0
Haddock	1	41	14	1	0	0	0	2
White Hake	0	4	0	1	1	1	0	0
Pollock	0	2	0	0	0	0	0	0
Atlantic Halibut	0	6	2	35	49	37	1	0
Cod, Haddock, Pollock	0	6	0	1	0	0	0	0

[1]1210 may be the result of a combination of size 12 and size 10 hooks used in a set (and entered in the log sheets) and converted to 1210 when entered into commercial landings data base.

Table 2. Number of commercial longline sets with halibut landings by hook size and division (2009-2013; MARFIS database).

NAFO Division	Hook Size				
	10-13	14-16	20	Not recorded	Other
3N	0	100	0	0	0
3O	0	102	0	15	0
3Ps	0	786	0	147	19
4V	230	3,206	2	156	80
4W	366	5,188	1	173	129
4X	5,418	10,585	2	351	428
5Y	11	172	0	10	9
5Z	1,515	32	0	20	4

Table 3. Proportion of halibut landings (with hook size reported) using hook size 14-16 by division and quarter (2009-2013). Cells with dashes (-) indicate no data.

NAFO Division	Jan-Mar	Apr-June	July-Sept	Oct-Dec	All months
3N	-	1.00	1.00	-	1.00
3O	1.00	1.00	1.00	-	1.00
3Ps	1.00	1.00	1.00	1.00	1.00
4V	0.99	0.96	0.85	1.00	0.94
4W	0.97	0.93	0.94	0.90	0.94
4X	0.71	0.76	0.58	0.11	0.67

Table 4. Percent commercial landings observed at sea by NAFO Division and quarter. Roughly 1% of all landings are from NAFO Divisions 5Y5Z. Here they are included with NAFO Division 4X landings.

NAFO Division	Quarter				
	Jan-Mar	Apr-June	July-Sept	Oct-Dec	All months
3N	132.3[1]	152.5[1]	42.8	0	97.5
3O	14.8	39.6	14.9	0	23.3
3Ps	13.9	16.9	29.4	8	16.8
4V	16.2	17.1	5.7	0	13.8
4W	9.6	6.4	0.1	0	5.5
4X5YZ	20.2	28	2.9	0	12.6

[1]Percentages greater than 100% arise from a mismatch between landings date and observer data

Table 5. The percent by weight of the total catch retained by quarter and division on halibut-directed observed sets between 2009 and 2013 (ISDB query: October 2014).

NAFO Division	Jan-Mar	Apr-June	Jul-Sept	Oct-Dec
3N	90.5	69.5	66.3	-
3O	77.8	70.1	83.8	-
3Ps	73.7	64.7	92.2	93.1
4V	83.8	83.3	91.6	0.0
4W	78.2	87.7	36.5	-
4X	79.6	81.8	84.7	-

Table 6. The proportion (of total retained weight) that was halibut by quarter and division on halibut-directed observed sets between 2009 and 2013 (ISDB query: October 2014). Also reported, the percentage (by weight) of halibut discarded by division. Cells with dashes (-) indicate no data.

NAFO Division	Jan-Mar	Apr-June	July-Sep	Oct-Dec	All months	Discard rate
3N	-	1.00	1.00	-	1.00	2
3O	1.00	1.00	1.00	-	1.00	5
3Ps	1.00	1.00	1.00	1.00	1.00	7
4V	0.99	0.96	0.85	1.00	0.94	10
4W	0.97	0.93	0.94	0.90	0.94	7
4X	0.71	0.76	0.58	0.11	0.67	13
5Y	1.00	0.94	0.96	-	0.94	-
5Z	-	0.01	0.02	-	0.02	-

Table 7. Ratio estimators used to calculate landings of bycatch species in the halibut fishery, by NAFO Division and quarter (1: January-March; 2: April-June; 3: July-September; 4: October-December).

Species	3N[1]				3O				3Ps			
	1	2	3	4	1	2	3	4	1	2	3	4
White Hake	0.00	0.15	0.10	0.00	1.06	0.56	0.09	0.61	0.29	0.40	0.06	0.10
Atlantic Cod	0.07	0.05	0.05	0.07	0.02	0.01	0.01	0.00	0.47	0.20	0.00	0.00
Cusk	0.01	0.01	0.01	0.01	0.02	0.05	0.01	0.00	0.00	0.02	0.03	0.03
Haddock	0.00	0.00	0.03	0.00	0.30	0.01	0.05	0.00	0.09	0.02	0.00	0.00
Greenland Halibut	0.06	0.00	0.00	0.06	0.15	0.02	0.06	0.00	0.00	0.00	0.01	0.01
Northern Wolffish	0.01	0.11	0.04	0.01	0.02	0.07	0.00	0.00	0.00	0.00	0.02	0.00
Striped Wolffish	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Spotted Wolffish	0.02	0.05	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Winter Skate	0.00	0.03	0.02	0.00	0.29	0.01	0.01	0.00	0.09	0.04	0.03	0.00
Thorny Skate	0.00	0.15	0.12	0.00	0.03	0.13	0.15	0.00	0.01	0.21	0.01	0.00
Smooth Skate	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.01	0.00
Barndoor Skate	0.00	0.04	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
White Skate	0.00	0.03	0.23	0.00	0.06	0.04	0.05	0.00	0.22	0.43	0.00	0.00
unidentified skates	0.66	0.07	0.00	0.66	0.03	0.12	0.03	0.00	0.36	0.68	0.08	0.01
Spiny Dogfish	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.03	0.00
Black Dogfish	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.02
Blue Shark	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Porbeagle Shark	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.03	0.01	0.00	0.00
Greenland Shark	0.10	0.07	0.00	0.10	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00

Species	4V				4W[1]				4X			
	1	2	3	4	1	2	3	4	1	2	3	4
White Hake	0.19	0.26	0.11	0.37	0.10	0.04	0.13	0.10	0.80	0.04	0.03	0.01
Atlantic Cod	0.17	0.09	0.10	0.46	0.01	0.02	0.01	0.01	0.19	0.24	0.26	0.94
Cusk	0.02	0.05	0.04	0.08	0.02	0.20	0.30	0.02	0.01	0.10	0.10	0.14
Haddock	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.08	0.01	0.02	0.09
Turbot (Greenland Halibut)	0.00	0.00	0.00	0.00	0.01	0.00	0.05	0.01	0.00	0.01	0.00	0.00
Northern Wolffish	0.02	0.01	0.01	0.00	0.05	0.01	0.00	0.05	0.00	0.00	0.00	0.00
Striped Wolffish	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spotted Wolffish	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Winter Skate	0.02	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Thorny Skate	0.05	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.06	0.01	0.01	0.00
Smooth Skate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barndoor Skate	0.01	0.00	0.03	0.00	0.12	0.08	0.08	0.12	0.23	0.02	0.06	0.00
White Skate	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unidentified skates	0.00	0.00	0.02	0.01	0.01	0.00	0.03	0.14	0.00	0.05	0.07	0.00
Spiny Dogfish	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07	0.00
Black Dogfish	0.05	0.03	0.01	0.02	0.03	0.01	0.01	0.03	0.00	0.00	0.00	0.00
Blue Shark	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00
Porbeagle Shark	0.03	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.01
Greenland Shark	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00

[1] Quarter 1 used estimate Quarter 4 as only one or no months were observed.

Table 8. Species caught as bycatch in the halibut longline fishery, including any Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and/or Species at Risk Act (SARA) status.

Species	Population	COSEWIC status	Last Assessment date	SARA status
White Hake	Atlantic and Northern Gulf of St. Lawrence population	Threatened	2013	No status
Atlantic Cod	Laurentian South population	Endangered	2010	No status
	Newfoundland and Labrador population	Endangered	2010	No status
	Southern population (4X5YZjm)	Endangered	2010	No status
Cusk	Atlantic Ocean	Threatened	-	No status
Thorny Skate	Arctic and Atlantic Ocean	Special concern	2012	No status
Smooth Skate	Laurentian-Scotian population	Special concern	2012	No status
Winter Skate	Southern Gulf of St Lawrence	Endangered	2015	No status
	Eastern Scotian Shelf – Newfoundland populations	Endangered	2015	No status
	Georges Bank-Western Scotian Shelf and Bay of Fundy	Not at Risk	2015	No status
Atlantic Wolffish	Atlantic Ocean	Special concern	2012	Special concern
Northern Wolffish	Arctic and Atlantic Ocean	Threatened	2012	Threatened
Spotted Wolffish	Arctic and Atlantic Ocean	Threatened	2012	Threatened
Blue Shark	Atlantic population	Special concern	2006	No status
Porbeagle	Atlantic Ocean	Endangered	2014	No status
Spiny Dogfish	Atlantic population	Special concern	2010	No status

FIGURES

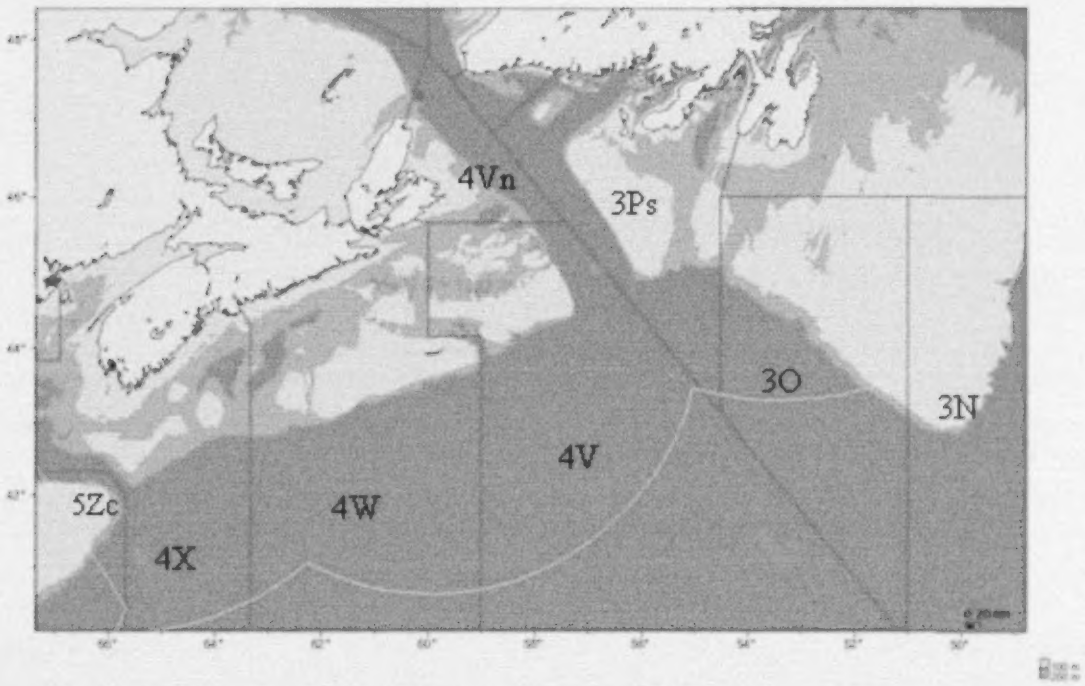

Figure 1. Management unit of Atlantic Halibut showing Northwest Atlantic Fisheries Organization (NAFO) divisions. Note that landings and observed sets in NAFO Division 5Z are not considered in this analysis.

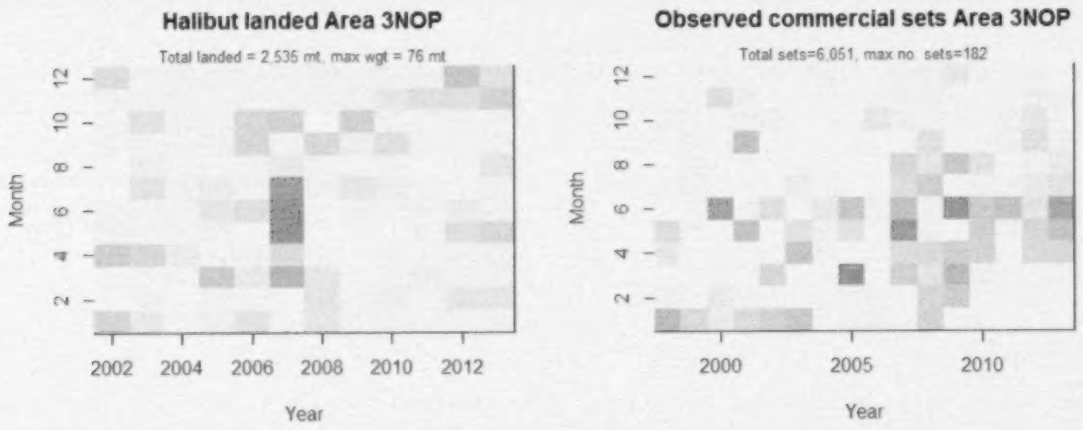

Figure 2. Distribution of commercial halibut landings (weight) by month from 2002-2013 in NAFO Divisions 3NOPs (left) and corresponding distribution of observed commercial sets directed at halibut from 1998-2013 (right). Colour darkens from white (no landings or no observed sets) to red (highest landings level of observed sets). The highest landed weight (max. wgt), and the highest number of sets (max. no sets) recorded in the matrix of month and year are reported above the graphs.

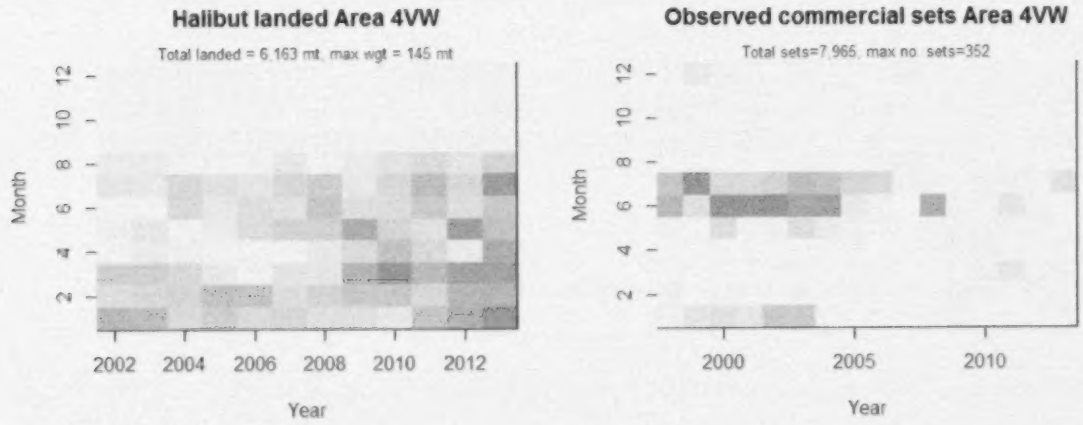

Figure 3. Distribution of commercial halibut landings (weight) by month from 2002-2013 in NAFO Divisions 4VW (left) and corresponding distribution of observed commercial sets directed at halibut from 1998-2013 (right). Colour darkens from white (no landings or no observed sets) to red (highest landings level of observed sets). The highest landed weight (max. wgt), and the highest number of sets (max. no sets) recorded in the matrix of month and year are reported above the graphs.

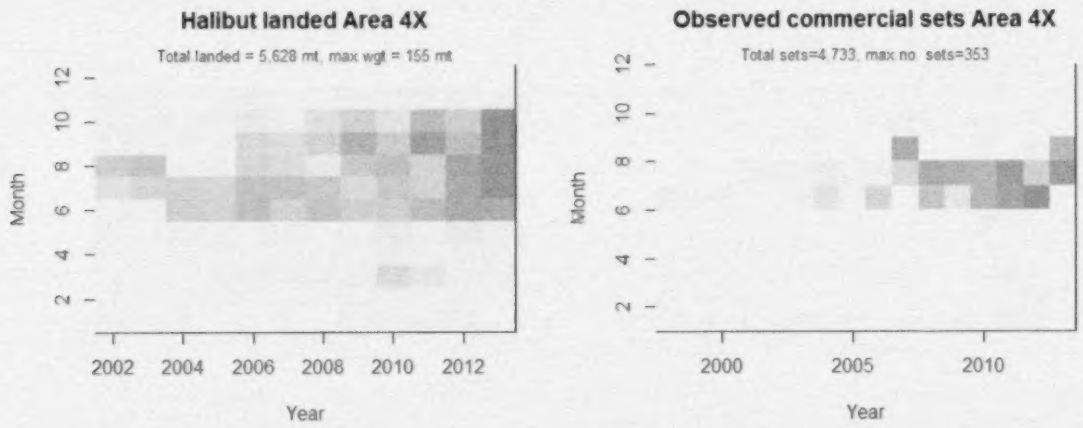

Figure 4. Distribution of commercial halibut landings (weight) by month from 2002-2013 in NAFO Division 4X (left) and corresponding distribution of observed commercial sets directed at halibut from 1998-2013 (right). Colour darkens from white (no landings or no observed sets) to red (highest landings level of observed sets). The highest landed weight (max. wgt), and the highest number of sets (max. no sets) recorded in the matrix of month and year are reported above the graphs.

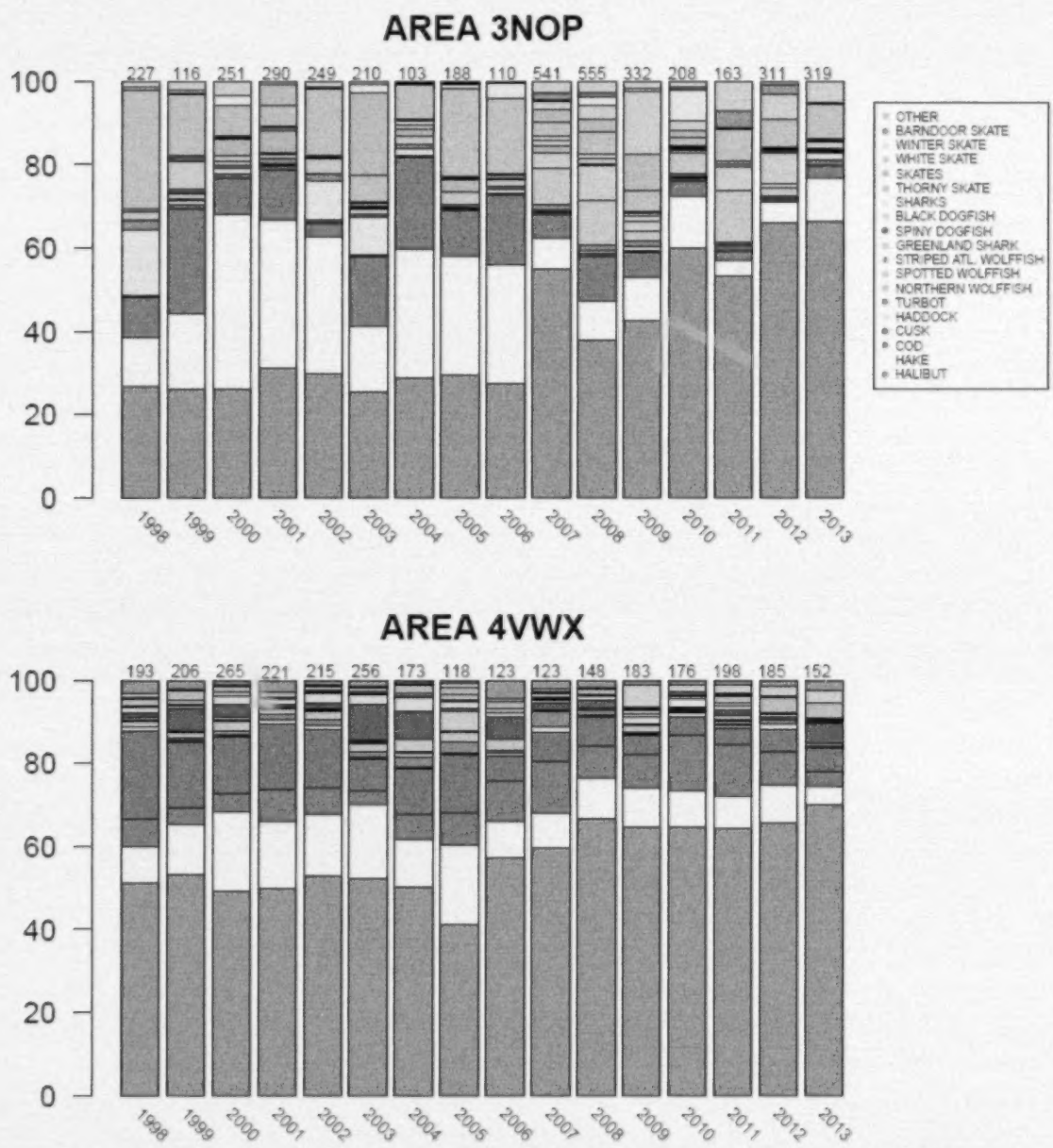

Figure 5. Species composition in observed fishing sets in NAFO Divisions 3NOPs (upper panel) and NAFO Divisions 4VWX (lower panel) conducted between 1998 and 2013.

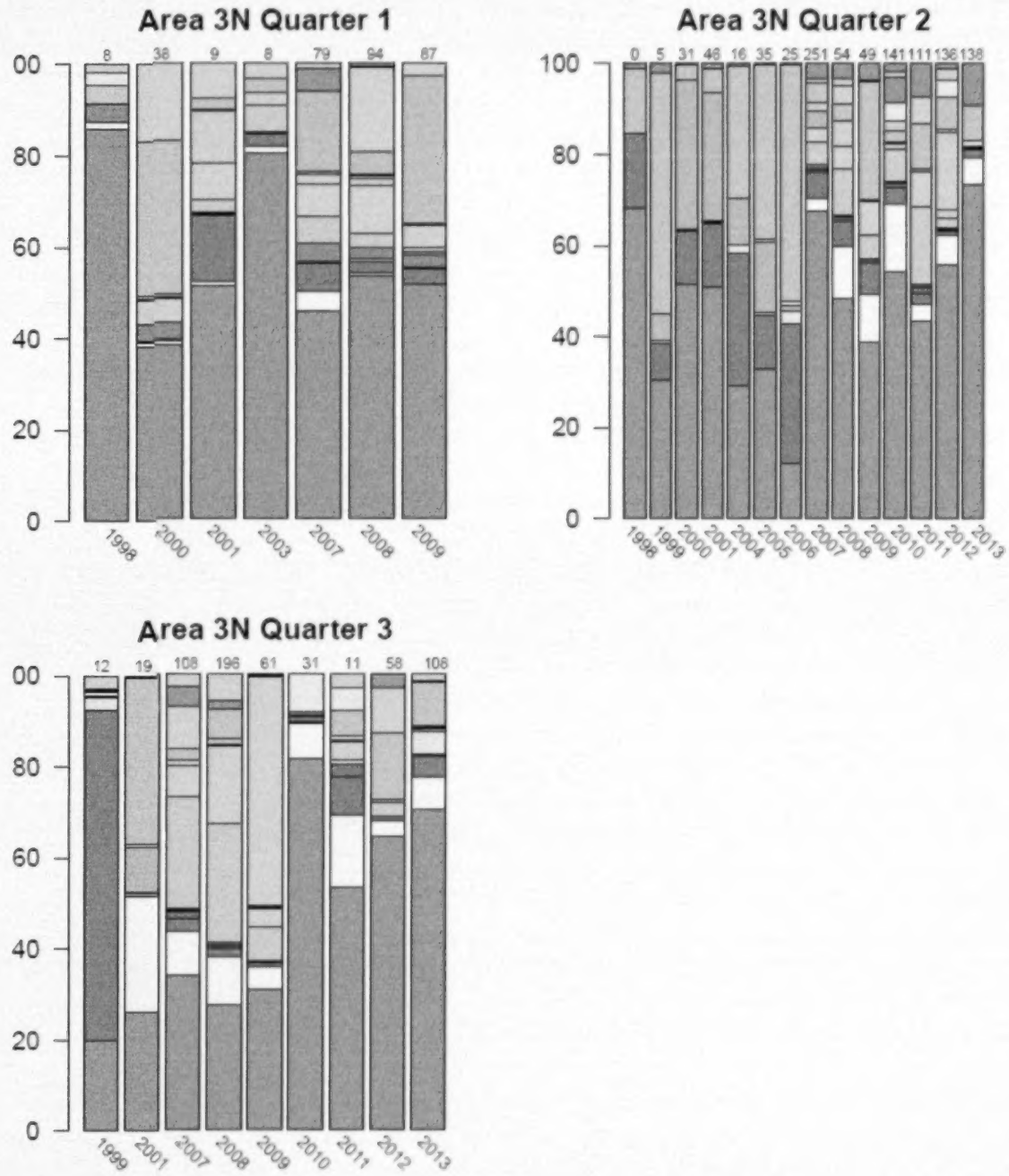

Figure 6. Percent species composition (by weight) in observed sets in NAFO Division 3N from 1998 to 2013 for quarter 1 (upper left panel), quarter 2 (upper right panel) and quarter 3 (lower left panel). Too few sets were observed in quarter 4, so no data is presented here. The number above the bars is the total observed catch (mt). The species legend is shown in Figure 5.

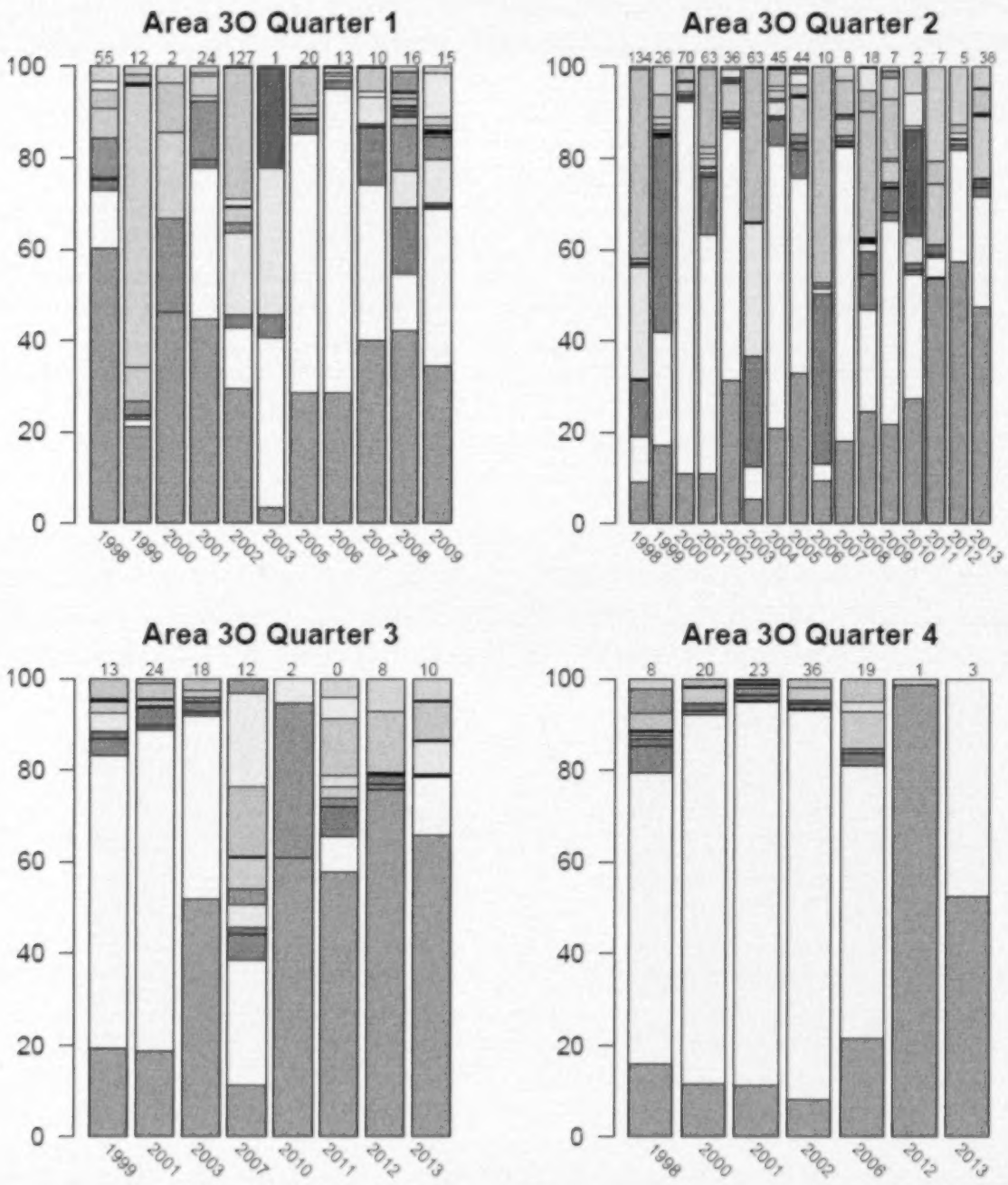

Figure 7. Percent species composition (by weight) in observed sets in NAFO Division 3O from 1998 to 2013 for quarter 1 (upper left panel), quarter 2 (upper right panel), quarter 3 (lower left panel) and quarter 4 (lower right panel). The number above the bars is the total observed catch (mt). The species legend is shown in Figure 5.

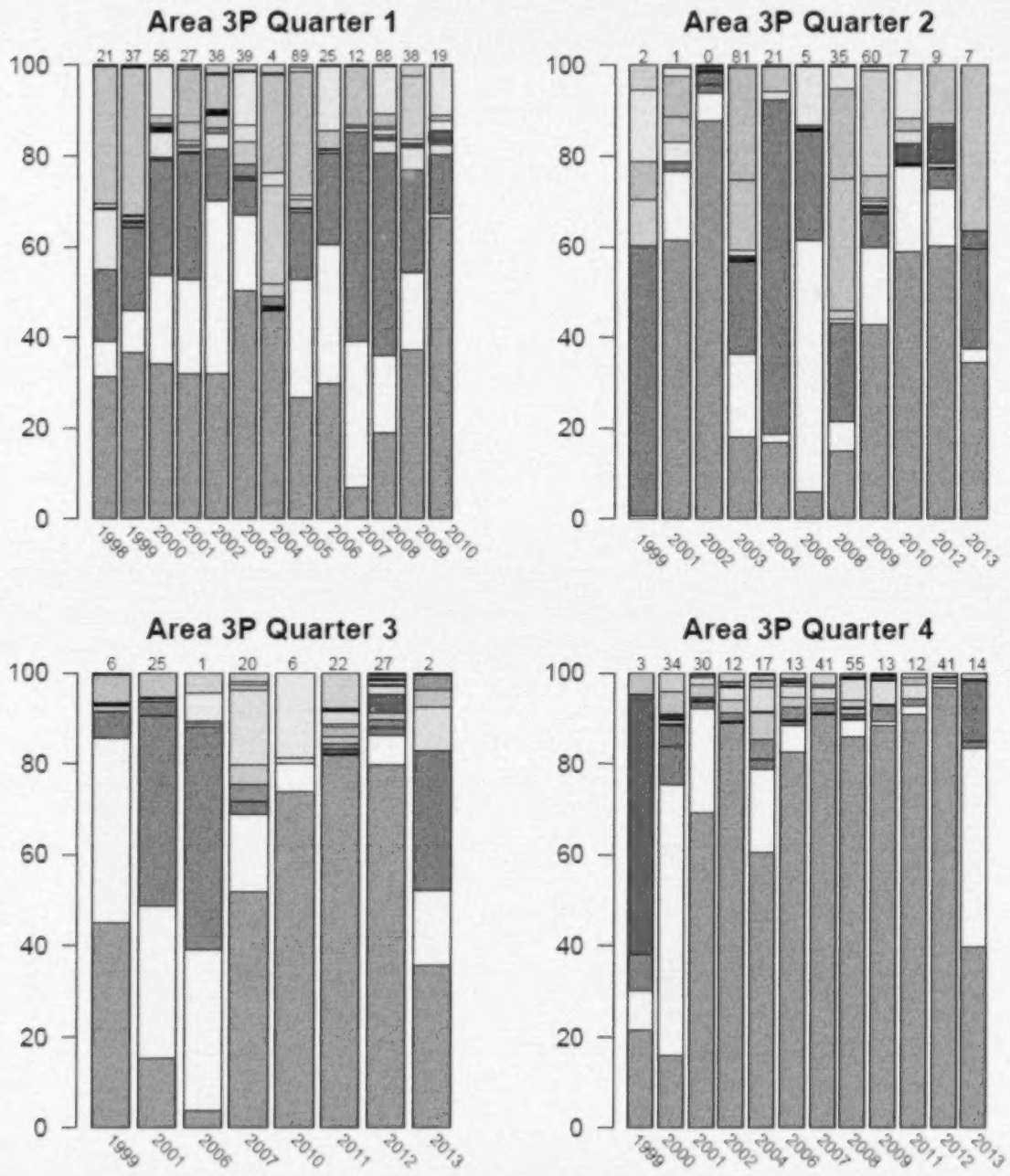

Figure 8. Percent species composition (by weight) in observed sets in NAFO Division 3P from 1998 to 2013 for quarter 1 (upper left panel), quarter 2 (upper right panel), quarter 3 (lower left panel) and quarter 4 (lower right panel). The number above the bars is the total observed catch (mt). The species legend is shown in Figure 5.

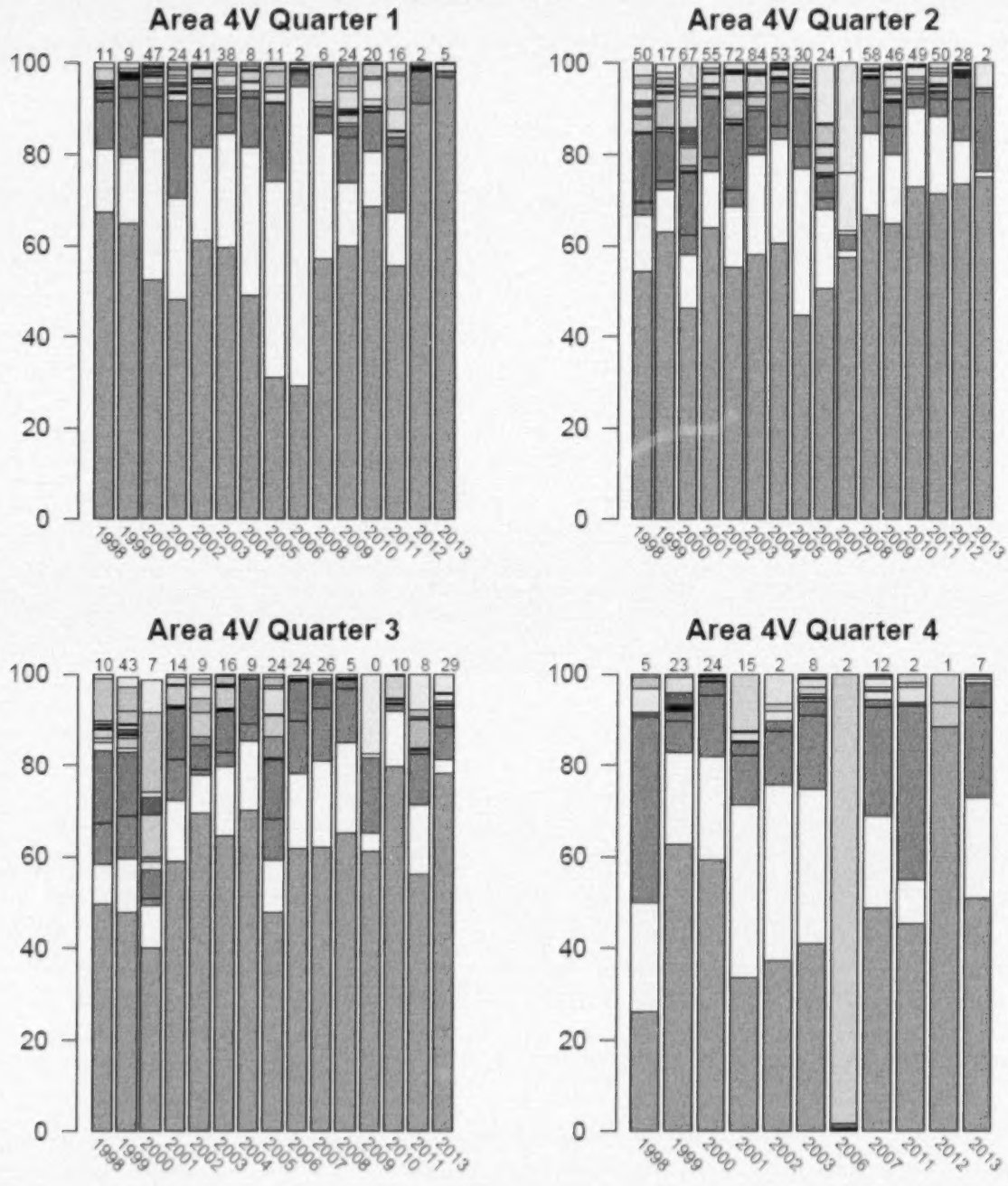

Figure 9. Percent species composition (by weight) in observed sets in NAFO Division 4V from 1998 to 2013 for quarter 1 (upper left panel), quarter 2 (upper right panel), quarter 3 (lower left panel) and quarter 4 (lower right panel). The number above the bars is the total observed catch (mt). The species legend is shown in Figure 5.

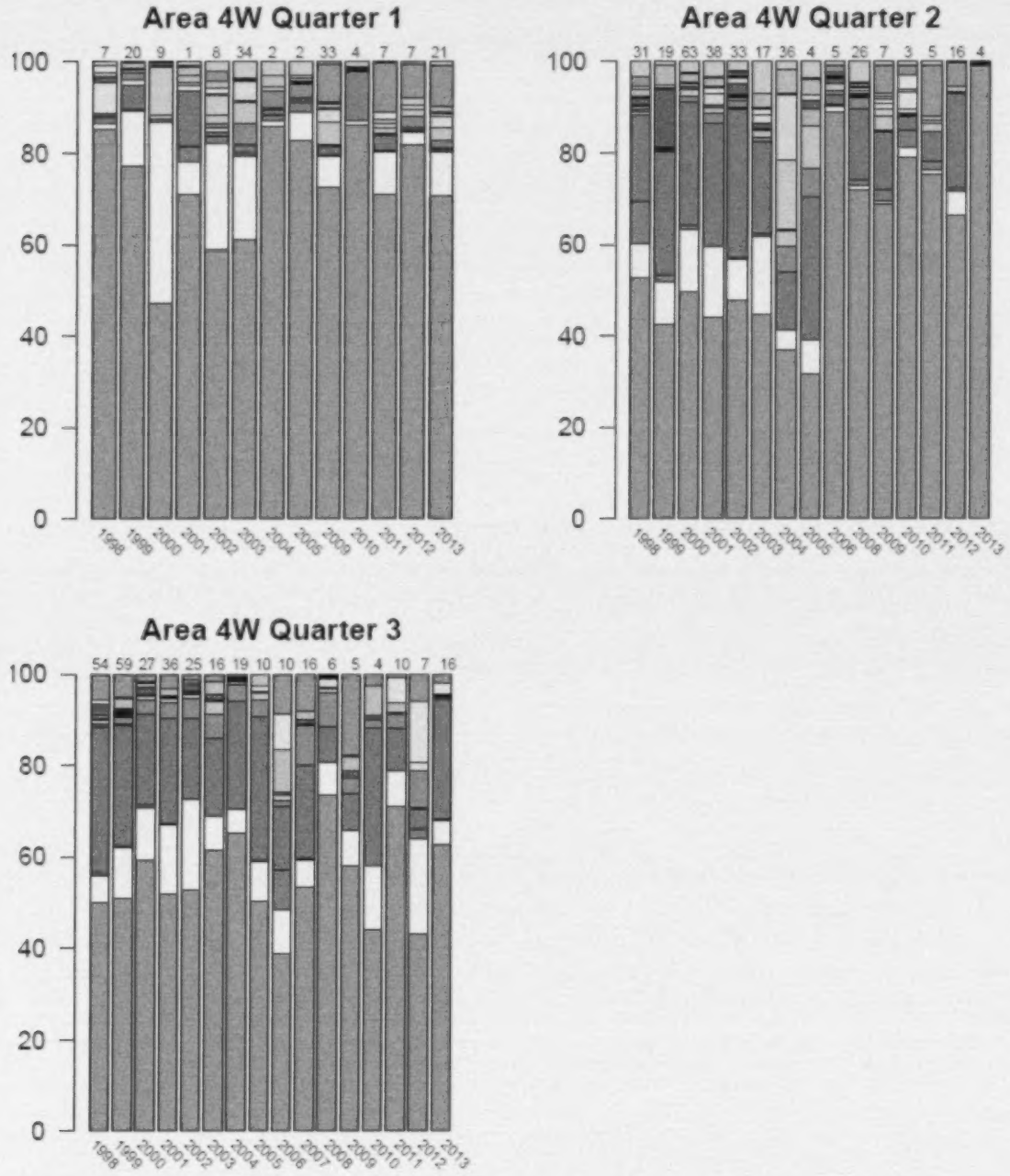

Figure 10. Percent species composition (by weight) in observed sets in NAFO Division 4W from 1998 to 2013 for quarter 1 (upper left panel), quarter 2 (upper right panel) and quarter 3 (lower left panel). Too few sets were observed in quarter 4, so no data is presented here. The species legend is shown in Figure 5.

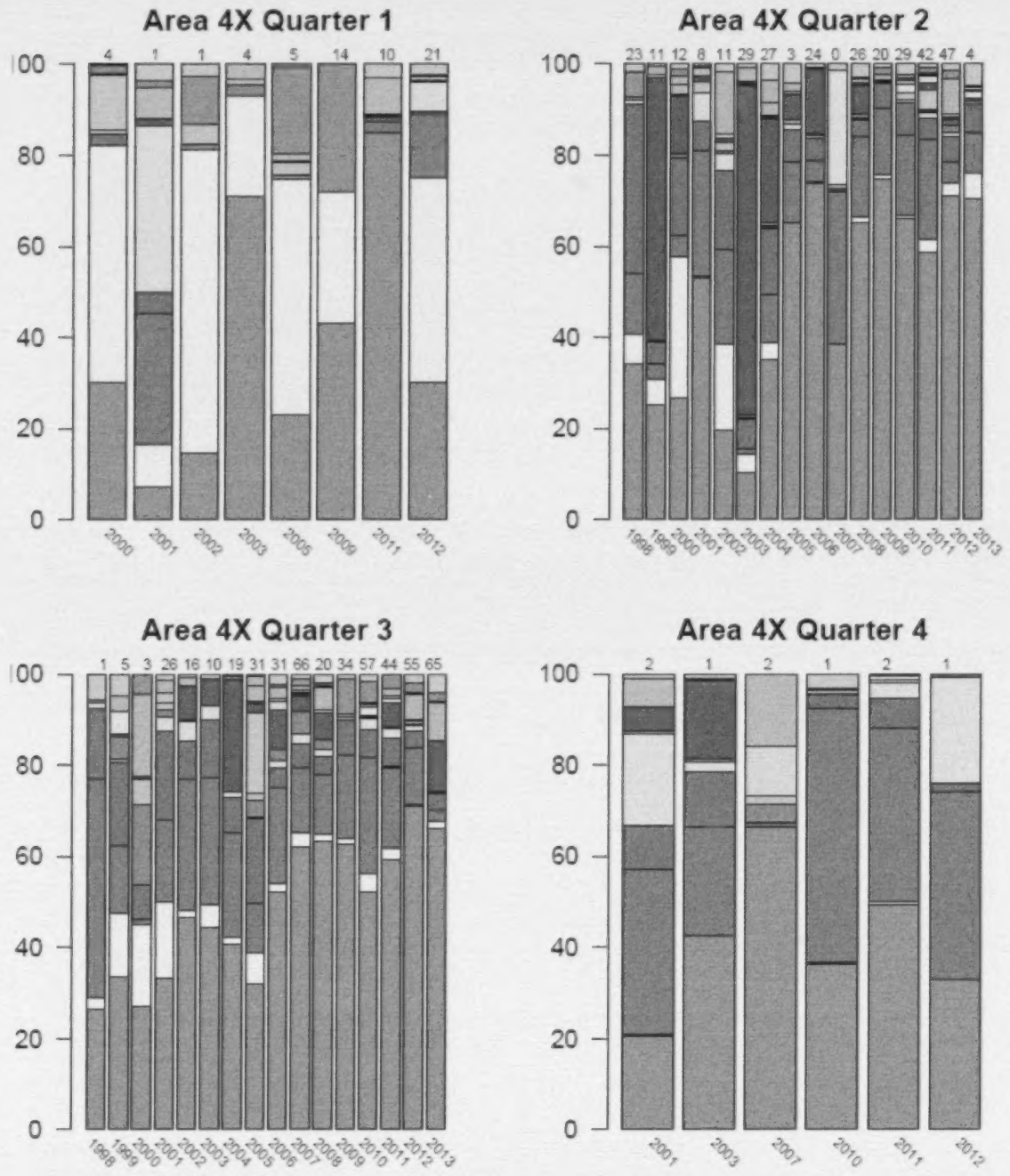

Figure 11. Percent species composition (by weight) in observed sets in NAFO Division 4X from 1998 to 2013 for quarter 1 (upper left panel), quarter 2 (upper right panel), quarter 3 (lower left panel) and quarter 4 (lower right panel). The number above the bars is the total observed catch (mt). The species legend is shown in Figure 5.

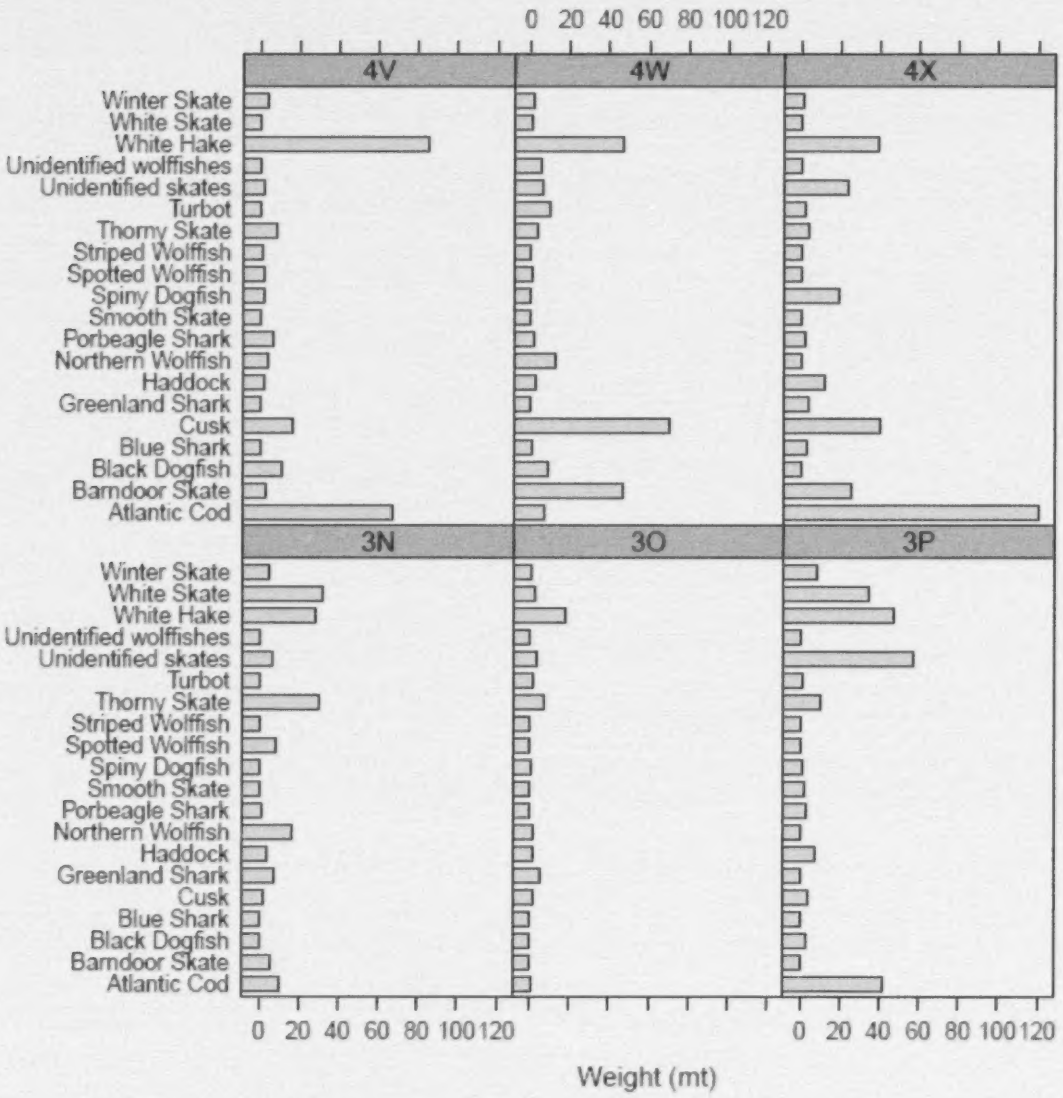

Figure 12. Estimated bycatch (mt) of species of interest in the longline fishery directing for halibut in 2013 calendar year by NAFO Division.